Explanatory models of regional innovation performance in Europe: policy implications for regions

Abstract

Research and Innovation Strategies for Smart Specialization (RIS3) was integrated as a key piece of the cohesion policy for the European Union (EU) for 2014-2020. A RIS3 is an innovative approach that seeks to increase economic growth and to create jobs in Europe by enabling regions to identify and develop their competitive advantages. During the recent years, more than 120 RIS3 have been developed, being a large-scale EU experience aimed to develop innovation-driven economic transformations at national and regional levels. The objective of this article is to explore the models that best explain innovative employment and the emergence of new markets in Europe's regions. For that purpose, the latest dataset of the Regional Innovation Scoreboard 2019 was used, and regressions performed to identify the main factors behind the impact of regional innovation. The results unveil the 'double edge role' that some variables have on regional innovation, indicating the difficulties of managing different trade-offs and of a standalone innovation policy strategy. Policy measures are discussed to best manage these critical compromises and increase the impact of RIS3.

Keywords: Innovation; Smart Specialization Strategies; RIS3; Regional Innovation Scoreboard; Europe; Policy

Introduction

The strategic innovation policy dates back to the 1950s and 1960s but only in the 2000s there was a change from 'market-based-policies' to 'state-based-policies' to foster technological development and address the grand societal challenges (Kroll 2019). The latest regional innovation policy has been transforming the landscape of European regions for the past years. McCann and Ortega-Argilés (2013) note that this new regional policy approach changed the perception of the role that innovation plays in economic development as it puts an emphasis on regions.

Research and Innovation Strategies for Smart Specialization (RIS3) have been drawn from Foray, David and Hall's (2009) research, and integrated in the cohesion policy of the European Union (EU) for the period 2014 to 2020 (Foray 2018). During this period, over 65 billion Euros (including national co-financing) were allocated to regions through the European Regional Development Fund (European Commission 2017b) and more than 120 RIS3 were developed (Foray 2018). These RIS3 are place-based strategies that build on regions and member states' assets, resources and socio-economic challenges, embracing a broad view of innovation including, but not limited to, technology-driven approaches supported by monitoring mechanisms (European Commission 2019e, 2019b, 2019d).

However, despite these efforts made by the European Commission to support RIS3, many regions did not lived up to expectations invested in them (Kroll 2019). For example, Muscio, Reid and Rivera Leon (2015, p. 168) argue that they do *"not sustain a virtuous cycle in terms of the capacity of these countries to close the gap with more advanced neighbours in Western Europe"*, suggesting a large gap in the performance of regional innovation between regions.

Regardless the increasing research on RIS3, existing studies focus mostly on the processes of design and implementation (see e.g., Chrysomallidis and Tsakanikas 2017; Capello and Kroll 2016), while ignoring its implications for the impacts on regional development (Lopes, Ferreira, and Farinha 2019). Particularly, there are still several challenges in the analysis of the economic impacts of these policies and a gap in empirical studies on the effectiveness of RIS3 (Varga et al. 2020; Sarkar, Bilau, and Basílio 2020). Lopes et al. (2018) suggest the development of studies to help find explanatory models of regional innovation performance.

At an overachieving level, there is the need to increase the knowledge on RIS3 considering that the current 2014-2020 period of Cohesion Policy is coming to its end.

Set against this background, the objective of this study is to contribute to RIS3 research by exploring the models that can best explain the drivers of regional innovation impacts on high-tech employment and new markets in a time of smart specialization. Compared to previous attempts (see e.g. Lopes, Farinha, and Ferreira 2019; Lopes et al., 2018), this research carries some novelties. First, it resorts to the latest dataset of the Regional Innovation Scoreboard 2019 which is the most comprehensive one to date[1]. Second, the Regional Innovation Scoreboard 2019 is comprised by a broad array of variables, including specific ones that concentrate on evaluating the impacts of RIS3 on regions' high-tech employment and market innovation. This allows to overcome the limitation of assuming only internal innovation of small and medium-sized enterprises as the primary goal of smart strategies by broadening its scope to the employment characteristics and to the diffusion of the innovation impacts within the regional territory.

Third, it explores the factors that best explain RIS3 impacts on regional innovation technological employment and new markets, enabling to evaluate and differentiate them, and to understand if any change to the strategic focus of the regional innovation policy could lead to more successful outcomes. Therefore, these novelties can advance the literature on how to shape regional policies towards RIS3 most important drivers,

[1] Compared to the Regional Innovation Scoreboard 2016 that includes 12 variables (European Commission 2016), the Regional Innovation Scoreboard 2019 comprises 17 variables (European Commission 2019c)

contributing to the readjustment of regional innovation policies aiming to increase their impact. Overall, this research allows to discover the main potential drivers, and their trade-offs, to leverage RIS3 high-tech employment and new markets impacts and catalyse regional economic development.

The article is structured as follows. The framing of the topic and its problematic have been made in this introductory section, followed by the review of the literature on RIS3 with an emphasis on the studies using the Regional Innovation Scoreboard and its main dimensions. Next, we explain the methodology of the study, such as the source of data and the method used for identifying the main explanatory variables of the drivers of RIS3 innovation impacts. Then, the results are presented, and the implications of the study discussed in the light of the results obtained. The article concludes with the limitations and the avenues for future research.

Theoretical insights to research and innovation strategies

Regional development policies have been gaining a fast importance at both academic and policy levels (Varga et al. 2020; Lopes, Ferreira, and Farinha 2019). These new regional policies were developed based on the concept of a smart specialization. Smart specialization emerged as an important policy agenda for science, technology and innovation for European countries on the face of important economic changes and trends such as: the diffusion of information and communication technology (ICTs); the increasing supply of research and development (R&D) and human capital; the globalization of production systems and of businesses R&D; the rise of services and of new global players; the austerity in European countries; the quests for saving public spending; and the re-emergence of a new industrial policy to revitalize manufacturing production activities (OECD 2013).

The central notion of smart specialization is that governments should focus their knowledge investments in activities that reflect domains where a region has a comparative advantage (specialization), or in emerging domains where entrepreneurs can develop new activities (diversification) with the aim of revealing the most promising areas of innovation in a particular region (Foray, David, and Hall 2009a). This means that smart specialization is ‘smart’ if based on a region’s strengths and characteristics (rather than replicating the strategies of well-known successful regions in the world), and ‘specialized’, if favouring regional actors’ concentration of resources and efforts on a limited number of priorities where the region excels (Marinelli, Elena-Perez, and Alias 2016; Varga et al. 2020; Sarkar, Bilau, and Basílio 2020).

Smart specialization evolved from EU's aim to strengthen its R&D activities through specialization, into an approach based on the diversification of regional economies and on fostering new entrepreneurial opportunities derived from specialized capabilities (McCann and Ortega-Argilés 2015). The concept has now turned into a central pillar of the EU’s cohesion policy and can be understood as the EU’s industrial policy (S. Radosevic 2017).

The main instrument for the implementation of smart specialization is the entrepreneurial discovery process that aims to put entrepreneurs into the driver’s seat (Varga et al. 2020). In other words and based on the concept of smart specialization, no single agent (governments, firms, R&D organizations) has a complete view of the economy, thus, the role of the policy is to coordinate and implement the discovery of new specialization by the targeted agents (S. Radosevic 2017; Varga et al. 2020). Regions are thus responsible to conduct a participatory public-private discovery process to identify the regional capabilities and to reach an agreement on the thematic priorities and on the fields of specialization (Benner 2019). This process is meant to create a RIS3 that represents the shared vision for the region supported by public and private agents (Foray, David, and Hall 2009b).

The use of evaluation tools (Kotnik and Petrin 2017) and the involvement of regional stakeholders in identification of the thematic prioritization themes is therefore crucial to the operationalization of a smart strategy (Lopes et al. 2018). This multi-stakeholder process implies not only the development of a common strategic view for the region, but also the identification of place-based domains of strategic potential, the development of multi-stakeholder governance mechanisms, the establishment of priorities and the employment of support policies to exploit the knowledge-based development of a region (Sotarauta 2018; Sarkar, Bilau, and Basílio 2020). Furthermore, these processes ensure that RIS3 are clearly driven by place-based fundamentals that stress the importance of local actors, knowledge and innovation resources in policy design (Barca 2009).

Overall, smart specialization is about a region's capacity to implement structural changes to its economy such as industrial diversification, modernization, or the development of radically new industries in a region (Foray, David, and Hall 2011).

Despite the well-developed theoretical foundations of smart specialization, some challenges still remain to empirically assess and analyse the real impacts (e.g., in employment or growth domestic product) of these policies (Varga et al. 2020; Sarkar, Bilau, and Basílio 2020). In this regard, research to compare and evaluate regional impacts within Europe constitutes a critical factor. Some tools were developed to support the need for a comparative perspective of place-based RIS3 (Pagliacci et al. 2019). An example is the Regional Innovation Scoreboard that establishes an assessment tool grounded on a set of dimensions and structural indicators to measure the innovative performance of EU and support the identification of their policy priorities (European Commission 2019a). These four main dimensions are: framework conditions, investments, innovation activities and impacts. An advantage of the Regional Innovation Scoreboard is that it promotes transnational and transregional learning that can eventually shift policy-makers beyond general assessments of their regional smart specialization strategies to more targeted analysis (Pagliacci et al. 2019). However, regardless of the availability of data, research using the Regional Innovation Scoreboard data is giving its first steps and is still limited (Blažek and Kadlec 2019; Lopes et al. 2018; Pater and Lewandowska 2015). The four dimensions are therefore critical to understand.

Framework conditions

Framework conditions concern mostly to the drivers of innovation performance external to the firm (see Table 1 for a detailed analysis of the core indicators used to set up regional framework conditions). The knowledge-based literature places human capital at the heart of the determinants for innovation capacity, arguing for the need to invest in human resources, skills and know-how (Pires et al. 2020). Human resources can be considered '*a source of the dynamic comparative advantages that govern the potential for innovation in the regions in the long term' and 'the only real capital*' (Landabaso 1997; p. 3). Both economic theory and experience suggest that intellectual capital has a fundamental role on modern economy (Pater and Lewandowska 2015) and among the most important economic preconditions for innovation activities to take place are the existence of a critical mass of actors and of available human capital (Eder 2019).

Research on smart specialization supports that innovative environments can be created by attracting skilled labour and focusing on endogenous human capital development (Sörvik et al. 2019). Even if environments considered 'innovation-friendly' can act as catalysts for supporting firms' innovativeness, the lack of qualified personnel can hinder innovation (European Commission 2017a).

Firgo and Huber (2014) argue that human capital is the most important predictor of convergence for poor regions as the percentage of population with tertiary education is related with a higher likelihood to grow above average (whereas the percentage of population with at most the obligatory education decreases that probability). In the particular case of RIS3, these skills are often related with ICTs education. For example, early on, Camagni (1992) noted that policy guidelines (particularly those for lagging regions), should concentrate on upgrading the existing human capital through vocation training, the orientation of education programs towards ICTs and the development of managerial and organizational capabilities. Following the same line of thought, Krammer (2017) also highlights the importance of the availability and skillset of existing human resources, suggesting developing more ICT programs and focusing on applied and niche ICT education (for RIS3 to increase competitiveness in lagging regions).

Investments

Investments are related with the role of public and private R&D expenditure (see Table 1 for a detailed analysis of the core indicators used to set up regional investments). Research has shown that the variation in R&D expenditure and in the innovation performance of a region is more profound within particular EU countries than the variation among these countries, suggesting the existence of regional factors shaping these differences (Oughton, Landabaso, and Morgan 2002; Blažek and Kadlec 2019).

The lack of R&D expenditure has been identified in the literature as a decisive factor for unsuccessful innovation policies (Eder 2019). Regions with high levels of R&D expenditure have a relatively high growth, as opposed to lagging regions that often exhibit lower levels of R&D expenditure (Rodríguez-Pose 2001).

Acknowledging the importance of the technological level of firms and societies for regions' innovation capacity creates an incentive to maximise that technological capacity. The most traditional way to achieve this is through an increase in investment in R&D that lead to a greater technological potential and consequently, innovation and growth (Rodríguez-Pose 2001). As Hunady, Pisar, Musa, and Musova (2017) note, from a regional strategy perspective, innovation support (particularly increasing R&D expenditures) constitutes a viable way to increase economic development in poorer regions.

These investments in R&D can be conducted at public and private levels. The regional policy view sustains that public investment in R&D in lagging regions spark economic convergence, supporting talent retention and generating spin-offs in lagging areas (Rodríguez-Pose 2001). Public R&D expenditures in a region (including that by government and higher education) also have the advantage of the potential to create intraregional spill overs (Roper and Love 2006). As for R&D investment in the private sector, the focus is often on the innovative competences and in the absorptive capacity of firms (Pires et al. 2020). Research shows how investment in R&D is crucial for firms and for the competitiveness of the regions as it works as a catalyst for efficiency and value creation (Sarkar, Bilau, and Basílio 2020).

Innovation activities

Innovation activities of small and medium-sized enterprises (SMEs), their innovativeness and linkages play a crucial role in the productivity of any region and nation (Alfonso-Gil, Saez-Cala, and Vinas-Apaolaza 2003). Landabaso (1997) argued for the importance of designing a regional technology strategy to promote co-operation between SMEs, the research community and public administration, and to assess technology requirements, audit local needs, capabilities and potential in order to improve regions' international competitiveness (see Table 1 for a detailed analysis of the core indicators used to set up regional innovation activities).

Firms innovate to improve and extend the quality of their products, to increase their market share, but also, to respond to changes in the environment such as new opportunities to expand their businesses or to threats from competitors and new entrants (European Commission 2017a). Regions' wealth is related to the competitiveness of their individual firms and industrial structures, hence, the importance of developing and strengthening sectoral business networks, clusters and business forums on innovation (Tödtling and Trippl 2005).

Inter-firm and public-private co-operation (between research organizations, government and industry) are key sources for regional innovation (Oughton, Landabaso, and Morgan 2002). Cooperation and networks formation constitute strategic options for SMEs to overcome the liability of smallness and promote innovation (Romero 2011). Inter-firm collaborations such as strategic alliances and joint ventures are also important managerial instruments for SMEs to improve their competitiveness and innovative capabilities by granting access to external knowledge, promoting synergies, fostering knowledge sharing, learning and creative changes (Piperopoulos and Scase 2009). An efficient uptake of innovations happen when local networks arise between firms, scientific research centres and local and regional business environments (Pater and Lewandowska 2015).

Highly innovative SMEs embedded in business networks are more likely to grow and to be more profitable than others (Piperopoulos and Scase 2009). Thus, policies should encourage the creation of these networks among SMEs to allow firms to create more innovative products and processes (Pires et al. 2020). The ability to create and implement intellectual property is also among the most significant drivers of an innovation system and the number of scientific publications, PCT patent applications, licence and patent revenues are considered the main indicators for driving innovation (studies using the Regional Innovation Scoreboard show how high-tech industries exhibited a high patenting intensity) (Mets et al. 2016).

Impacts

Because innovation is a driving force of regional development, one of the primary aims of regions (particularly lagging ones) is to increase their innovation performance (Hunady et al. 2017) (see Table 1 for a detailed analysis of the core indicators used to set up regional impacts). As noted by Landabaso (1997; p. 2) early on, "*technological innovation is probably the single most important factor that may contribute more to the creation of [...] regional competitive advantages*". Worrall (2007) suggest that a way to increase the development of lagging regions is for businesses to move into more high value adding and knowledge-intensive economic activities.

This can be achieved by changing the economic structure (e.g., composition of the human capital, degree of R&D expenditures and the characteristics of the firms) of regions with a subsequent impact on their high-tech employment and new sales. Pylak and Wojnicka-Sycz (2017) show that increasing the proportion of people with education is a path to achieve a high economic growth. Likewise, increasing the degree of R&D expenditures contributes to innovation (whenever regions hold the complementary skills to support knowledge generation and absorption) (Charlot, Crescenzi, and Musolesi 2015; Hunady et al. 2017). Additionally, while weak linkages between the actors in innovation systems limit the ability of research to be commercialized into new products (Muscio, Reid, and Rivera Leon 2015), collaborations increase the change of successful products innovations in terms of share of new products in sales and also the amount of innovation spending (Inzelt and Szerb 2006).

As Pylak and Wojnicka-Sycz (2017) argues, lagging regions can change the development path and achieve high growth if they increase – the proportion of growth domestic product spent on R&D and of business expenditures as part of R&D outlays, the proportion of people employed in science and technology, the share of high tech industries, the connection between technology and innovation activity – although this involves changing and improving regions' innovation models. As follows, the methodology adopted to identify the two explanatory models for the impact drivers of RIS is presented.

Methodology of the study

As follows, the source of data and variables of the study are described, followed by the methods used to analyse the research data.

Research data and study variables

The data used in this study was retrieved from the Regional Innovation Scoreboard 2019. The Regional Innovation Scoreboard can be considered the extension of the European Innovation Scoreboard (EIS) (European Commission 2019c). The annual EIS seeks to provide a comparative assessment of research and innovation performance in Europe and help its Member States assess the key areas in which they need to focus to boost innovation (European Commission 2017a)[2]. The EIS measurement framework has been significantly revised in 2017 in order to: better align the EIS dimensions with changing

[2] In addition to information on innovation performance, the Regional Innovation Scoreboard also classifies regions as: innovation leaders; strong innovators; moderate innovations; and modest innovators (see https://ec.europa.eu/growth/industry/policy/innovation/regional_en for an overview of regions classification)

policy priorities; continuously improve the quality, timeliness and analytical soundness of indicators; and ensure a better capture of the important phenomena in fields such as digitalisation and entrepreneurship. The Regional Innovation Scoreboard uses as many indicators possible as the EIS, but while the EIS 2019 uses the same indicators used in the EIS 2018, the results for 2017 in the EIS 2018 are not the same results as the results of 2017 in the EIS 2019. As noted by the European Commission (2019a) 'European Innovation Scoreboard Methodology report', several indicators have been revised in the external sources from which the data was extracted, and some data transformations have been applied to a slightly different set of indicators resulting in different normalised scores. This means that results are not always fully comparable between yearly datasets. In addition, the use of this dataset carries other limitations such as: data inability to capture some regions' specificities; missing data regarding a few regions' indicators; the fact that a portion of the indicators of the Regional Innovation Scoreboard is overlapping, which constitutes a limitation by itself (Pater and Lewandowska 2015); and issues related to the mathematical and statistical methods for aggregating indicators into composite measure (Carayannis, Goletsis, and Grigoroudis 2018; Garcia-Bernabeu, Cabello, and Ruiz 2020).

Nevertheless, the Regional Innovation Scoreboard constitutes an important tool to examine research and innovation performance in EU's regions, and is considered one of the most suitable innovative performance indexes tailored for specific geographical contexts (Arbolino, Boffardi, and De Simone 2019). The full dataset was used including its 17 indicators distinguishing four dimensions (analysed above) and covering 23 EU State Members and 238 regions (European Commission 2019c). Table 1 presents an overview of the study variables included in each dimension.

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TABLE 1 HERE

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At its genesis, smart specialization is a framework that shows how regional framework conditions, but particularly investment policies on R&D and innovation can influence economic, scientific and technological specialization of regional economies (OECD 2013). Thus, for this research purpose, the two Regional Innovation Scoreboard 2019 'impacts' variables were chosen as our dependent variables. This approach takes into account the EIS 2017 framework revision that sought to distinguish between framework conditions, investments in innovation, firms' innovation activities and the impacts of these activities, namely, their economic effects in two dimensions: employment impacts and new market sales impacts (European Commission 2017a). These two variables are representative of the main goals of RIS3 such as changing the employment structures of a regional economy and evaluating emerging trends regarding entrepreneurial discoveries and new activities (Foray and Goenega 2013).

Methods

The objective of this study is to explore the models that best explain RIS3 impact variables. For that purpose, a regression approach was adopted. Regression analysis intend to figure out the influence of independent variables on dependent variables, to provide relationships between independent and dependent variables and to estimate the dependent variable based on the changes of a set of independent variables (i.e., when the goal is to understand the causal influence on a population outcome). Usually, it is used as methodology with two different research aims: explanation and prediction (Jeon 2015).

Considering the exploratory nature of this study, we resorted to a regression method using the stepwise automatic procedure to identify the best predictor variables for the Regional Innovation Scoreboard 2019 impact dependent variables (following Lopes et al., 2018). The use of the stepwise regressions model has the advantage of selecting significant variables by screening several explanatory variables through parameter inference (Jun et al. 2015) and has been recently used in the fields of geography, planning, sociology and political science (see Escalona-Orcao, Sáez-Pérez, and Sánchez Valverde-García, 2018; Li et al., 2020; Lopes et al., 2018). However, this method is not without its flaws, with one of its major criticisms being the fact that is considered more data than theory driven (Lewis 2007; Henderson and Denison 1989)[3].

Stepwise regression is based on fitting a regression model in which the choice of the explanatory predictor variables is carried out through an automatic procedure (Jeon 2015). In other words, whenever the stepwise methods inserts a new variable in the model, the significance of each variable is assessed and the variable that does not hold a, or that holds the least meaningful explanatory capacity is excluded from the model, with the process being repeated until all variables excluded from the model are non-significant (Lopes et al. 2018).

The data collected from the Regional Innovation Scoreboard was inserted into SPSS 20.0 software (and following the RIS3 framework), two separate models were run in order to model the effects on our two dependent variables: 'Employment in MHT manufacturing & knowledge-intensive services' (henceforth hi-tech employment for reasons of parsimony) and 'Sales of new-to-market and new-to-firm innovations' (henceforth new sales for reasons of parsimony). Starting with hi-tech employment, we have to delete the variables that were not statistically significant (p-value < 0,05), one by one, always

[3] An attempt to overcome this limitation is the explanation on the existing associations between the four Regional Innovation Scoreboard dimensions in the theoretical section of the paper

starting with the variable that holds the least statistical significance. A similar procedure is applied to the new sales variable.

Results

This section presents the summaries of the models and the coefficients of the regressions. As noted, for each model, the R Square of the upper model obtained by the stepwise method has to be examined, which is of 0,676 and 0,692, respectively. This means that the obtained models explain 67,6% of the variance in the dependent variable hi-tech employment and 69,2% of the variance in the dependent variable new sales, which can be considered satisfactory[4]. Table 2 presents an overview of the obtained models for each dependent variable, respectively.

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TABLE 2 HERE

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For each dependent variable, the coefficients that allow writing the equation of the linear regression for the best model obtained are presented. Additionally, the Variance Inflation Factors (VIF) scores and tolerance values were examined to search for multicollinearity, i.e., when the correlation between the independent variables in the model adversely influence the results of the regression (Escalona-Orcao, Sáez-Pérez, and Sánchez Valverde-García 2018). All VIFs were below 10 and tolerance values above 0,1 meeting the thresholds for the non-existence of multicollinearity (Hair, Black, Babin, Anderson and Tatham, 2006). Table 3 presents the coefficients of the two regressions.

[4] Correlations among variables are provided in the Appendix (Cohen et al. 2013)

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TABLE 3 HERE

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The interpretation of the models is based on the variables that compose them, the order in which they appear, and the explanatory power offered by each one, as these aspects are essential for a complete understanding of the results. The linear regressions for the two impact variables are given by:

- Hi-tech employment = 0,210 + 0,496* *R&D expenditure business sector* + 0,192* *Population with tertiary education* – 0,186* *Lifelong learning* + 0,178* *Public-private co-publications* – 0,145* *Innovative SMEs collaborating with others*

- New sales = 0,126 + 0,615* *Most-cited publications* + 0,291* *Innovative SMEs collaborating with others* – 0,197* *Public-private co-publications* – 0,136* *Lifelong learning* + 0,129* *Non-R&D innovation expenditures* + 0,122* *Trademark applications*

Discussion

This article claims that regional innovation impacts, such as technological employment and new sales (which are expected to increase regional competitiveness), are driven by framework conditions (human capital), degree of investment, and firms' innovative activities (linkage or process innovation)[5]. Overall, the results support the existence of these effects. However, although they share common variables, the RIS3 technological employment and sales impacts are also explained by different predictors. Figure 1

[5] For example, Romer (1990) endogenous growth theory poses that economic growth is strongly influenced by human capital and the rate of technological innovation; Innovation is also considered one of the key factors behind regional growth (Garcia-Bernabeu, Cabello, and Ruiz 2020)

presents an overview of both models highlighting the common variables with a similar and opposed effect on the impact dependent variables.

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FIGURE 1 HERE

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The role of the framework conditions dimension is complementary; however, lifelong learning was found in the two models to have a negative relationship with both hi-tech employment and new sales. Lifelong learning is measured by the share of population aged 25-64 enrolled in education or training to improve knowledge (European Commission 2019c). In turn, 'Population with tertiary education', which is based on population aged 25-34 with tertiary education, had a positive effect on hi-tech employment. The higher the population aged 25-34 with tertiary education, the higher the human resources available for more innovative firms and therefore, higher high-tech levels of employment as more educated people have better job prospects (OECD 2012). Although lifelong learning can be useful for personal and professional development, it may concern to knowledge that does not find application in the particular field of new technologies. For example, Kassim, Buang and Mohamad (2019) argue that while lifelong learning develops human capital, SMEs employers are more focused towards employees working experience, working commitments and social skills. These results are only partially supported in the literature. Dima et al. (2018) and Zygmunt (2020) for example, found both a positive relationship of tertiary education and lifelong learning on competitiveness and on firms' innovation activities, respectively. This establishes the need to differentiate and better understand the roles of the various stages of education on knowledge creation and, particularly, on regional innovation performance. Additionally, 'Most-cited publications' emerged as the strongest predictor of 'New Sales', stressing the importance of the quality of the research and how it (often) translates into 'marketable' innovations (Zygmunt 2020). Jaffe, Trajtenberg and Fogarty (2000) argue, although with some reservations, that citations are indicative of knowledge diffusion[6]. Zygmunt (2020) also note that highly cited publications are crucial for knowledge creation, contribute to the diffusion of high-quality knowledge among universities and firms, and, were found to positively influence firms' new product and process innovations.

Regarding the investment dimension, the models' findings can be understood as complementary in the sense that R&D and non-R&D expenditures positively contribute to innovative employment and market performance, respectively. Increasing the R&D expenditure in the business sector emerges as the most important predictor for hi-tech job employment. In the same way, 'Non-R&D innovation expenditures' which are related with expenses in patents and licencing for the diffusion of technology and ideas has a positive influence on new sales. Several studies support the positive effects that R&D has on firms' performance and competitiveness, alongside its role for activating a region's potential (Květoň and Horák 2018). Regions should therefore be able to exploit and market their R&D assets and their generated knowledge in a an effective and regularly way (Asheim, Grillitsch, and Trippl 2017).

The innovative activities dimensions present the most intricate findings as the models share two explanatory variables, however, showing trade-off effects with opposing results.

The variable 'Innovative SMEs collaborating with others' has a negative effect on hi-tech employment but a positive one on new sales. Lopes et al. (2018) have also found mixed effects regarding SMEs collaborations as it hindered SMEs innovation on the most

[6] See Nelson (2009) for details on publications impact on innovation diffusion

developed regions, but in turn, contributed to innovation in lagging regions, highlighting the role of regions' heterogeneity. For example, SMEs collaboration can decrease high-technology employment as SMEs may be able to reach the same results by engaging in partnerships, rather than by hiring new personnel. On the other hand, collaborations and partnerships between SMEs enhance the sales of new-to-market and new-to-firm innovations as firms take advantage of these inter-firm interactions and of partners know-how to build synergies and to develop more innovative products. The establishment of these collaborations lead to the diffusion of innovative products and can be strategically used by firms, but it can be at the cost of decreasing the innovative employment.

Similarly, the variable 'Public-private co-publications' has opposing effects in the two models. On one hand, it exerts a positive effect on hi-tech employment but on the other hand, has a negative effect on new sales. Kaiser and Kuhn (2012) research supports our findings as they found that public-private research partnerships have an immediate impact on patent counts and employment growth, but no impact on valued added nor on labour productivity. This shows that while the linkages between business and public sector researchers generate high-technology employment, that does not necessarily translate into new to firm and market inventions. This is indicative that some efforts can be lost during these collaborative processes. However, this can also be explained as not all partnerships are directed intended at developing new high-tech products nor have a short-term impact. For example, research conducted at higher education institutions may result in an invention, but not necessarily in the creation of a practical solution that can be put into practice or commercialized (Chybowska, Chybowski, and Souchkov 2018). In the pharmaceutical industry, new drugs development time-to-market takes several years (Prašnikar and Škerlj 2006). Finally, 'Trademark applications', which is related with the intellectual property of the innovations and is indicative of an intention to use or to reserve a mark before launching a product into the market, positively affect new sales.

In summary, the fact that the two RIS3 impact variables have distinct drivers, although sharing some of them with opposed effects, stresses the difficulties of developing a stand-alone strategy that is able to manage all the trade-offs among those divers.

Policy implications

Some policy implications can be drawn. The findings highlight the difficulties of a standalone RIS3 to manage different drivers and trade-offs to meet all the aimed regional impacts. In particular, equally targeting the same policy variables can produce conflicting effects on innovation impacts of regions, highlighting the need for RIS3 to contextualize their regional priorities and prepare different actions that can complement and foster those dynamics, instead of exacerbating their opposing effects. Policymakers should thus consider these limitations and complement RIS3 with other supporting policies. A particularly challenging aspect is managing collaborations. Existing research in the field of management supports the link between firms' strategic alliances and their innovative performance (Rothaermel and Deeds 2004; Shan, Walker, and Kogut 1994). For policymakers, one possible path to retain the benefits of private interfirm collaboration is to promote strategic agreements between SMEs because of their influence on innovation and new product development. At public-private level, governments can focus on already innovative firms when subsidizing public-private R&D collaborations (Kaiser and Kuhn 2012).

A path to improve regional innovation performance is to promote structural changes, although considering EU regions' heterogeneity. Two innovation policies that can foster this process are the development of human capital and investment in R&D. Blažek and

Kadlec (2019) indicate that SMEs cooperation takes place in regions with stronger analytical bases (science-based), but that regions often lack labour force with analytical knowledge (as this knowledge concentrates more on metropolitan areas). Additionally, although the EU ranks well on human capital and schooling years, results are not so good regarding the quality of education in the fields of math and sciences, suggesting education quantity to be a lesser issue than quality (Paliokaitė 2019). In this sense, education policies should promote a more focused approach towards formal education as they influence regions' capacity to innovate, contributing to regions' human resources availability, and because innovation demands the existence of a permanently updated working force capable of dealing with new technologies.

Also, R&D is crucial to the design of new innovation policy measures, particularly considering some EU regions (e.g., several EU countries have private levels of R&D five times below the EU average) struggle to absorb such investments (Paliokaitė 2019). Furthermore, R&D support have uneven regional effects according to the maturity of their regional innovation system (Květoň and Horák 2018). In this sense, public expenditure can contribute to provide more support services to innovation. New policies should be directed at investments in businesses such as start-ups, knowledge-based foreign investment and businesses transformation towards more innovative activities, particularly in lagging regions, contributing to move these regions towards a knowledge-based economy through technology and increase firms' competitiveness in a context of decreasing labour cost competitiveness (Paliokaitė 2019).

In general, since regions have different economic structures and considering "*one size does not fit all*" (Tödtling and Trippl 2005; p. 1203), tailored regional strategies should consider a region's innovation needs as well the significant trade-offs among different policy measures. Most countries in Europe are lagging-behind, suffering from the lack of skilled human capital and making them less prone to innovation (Paliokaitė 2019). Hence, policies for more developed regions should focus on enhancing market performance (as they already possess the necessary human capital, regional innovation infrastructures and absorptive capacity), while lagging regions may need to focus first on policies to develop their human capital and R&D absorptive capacity. Even if changes in an economic base are slow, a critical mass of analytical knowledge constitutes a crucial factor for economic and innovation performance (Blažek and Kadlec 2019).

Conclusions

Smart specialization "*is a new word to describe an old phenomenon: the capacity of an economic system (a region for example) to generate new specialities through the discovery of new domains of opportunity and the local concentration and agglomeration of resources and competences in these domains*" (Foray, 2015; p. 25). The goal of smart specialization is to promote smart, sustainable and inclusive growth in Europe's regions. However, as noted, innovation policies have not necessarily led to higher innovation capacities (Muscio, Reid, and Rivera Leon 2015) and several EU countries are still lagging in innovation performance (Paliokaitė 2019).

The objective of this study was to identify the explanatory factors that can contribute the most to innovative employment and markets. For that purpose, data on the Regional Innovation Scoreboard 2019 was used and, based on the European Commission (2019a) report, two impact variables were considered: *i)* high-tech employment, that captures the share of employment in high technology in both manufacturing and services and is expected to generate creative and inventive activity increasing productivity; and *ii)* new sales, that captures simultaneously the status of the state-of-the-art and the diffusion of technology. For each impact variable, a model was estimated. The results of the study carry several implications and challenges for regional innovation policy.

The findings highlight the difficulties of a standalone RIS3 to manage different drivers and trade-offs to meet all the aimed regional impacts. The results point to the need for regional policies to redirect the concept of lifelong learning and concentrate efforts on a ‘quality-driven’, rather than a ‘quantity-driven’ education system, with an emphasis on developing human resources (particularly formal learning) and on building an attractive research system (emphasizing hard skills on key areas). Furthermore, key policy directions are underlined by this research such as the role that R&D and non-R&D investment have both on high-tech employment and innovation, and the importance of complementing a RIS3 with other supporting policies that mitigate its shortcomings.

One of the contributions that derives from our results is the challenge on how to effectively manage private and public linkages as managing these linkages have a direct implication on employment and innovativeness. Policy measures should focus on promoting specific forms of partnerships and linkages so that they are also likely to generate employment. In addition, RIS3 should consider regions’ heterogeneity and own characteristics (knowledge-bases mix, R&D effects, regional innovation systems, regional actors, innovation needs and goals). More developed regions may focus on RIS3 variables that enhance market performance such as polishing their education system quality and fostering private partnerships. Lagging regions frequently lack the resources of their more developed peers (Pires et al. 2020) and may instead target technological employment through policies that increase human capital availability, private investment and public-private partnerships.

Limitations and future research directions

The research resorts to the Regional Innovation Scoreboard 2019 dataset and considers its impact variables as the 'desired' outcomes of RIS3. A limitation of this approach is its economic standpoint on what should be the impact of RIS3, as in this study, is based on high-tech employment and innovation outputs only. However, Foray (2018; p. 1506) notes that RIS3 "*does not focus only on the industrial and economic renewal of traditional sectors, many regions have seen it as an opportunity to support the modernisation of their traditional sectors*". Moreover, the variance explained of the two dependent variables, although satisfactory, leaves room for the existence of other important factors that were not considered. For example, there are other factors that may impact innovation such as corruption (Anokhin and Schulze 2009), culture (Silva and Moreira 2017) or the institutional setting (Billon, Marco, and Lera-Lopez 2017).

Some future avenues of research are proposed. Future studies should consider a broader definition of impact that goes beyond the economic standpoint and include variables such as the scope of innovation. The most recent literature on territorial innovation supports for the importance of going beyond high-tech innovation and economic outcomes and examine other changes such as environmental or cultural ones, that can generate important spillovers for regions and promote green growth and wellbeing (Eder 2019; Pires et al. 2020). New and more robust theoretical models can also be developed including complementary metrics to the Regional Innovation Scoreboard 2019 to generate more holistic perspectives on RIS3 impacts.

Appendix

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APPENDIX 1 HERE

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Table 1 – Regional Innovation Scoreboard 2019 study variables

Dimension/Item	Description of the item
FRAMEWORK CONDITIONS	
Population with tertiary education	This is an indicator of the supply of advanced skills. It is not limited to science and technical fields, because the adoption of innovations in many areas, including the service sectors, depends on a wide range of skills. The indicator focuses on a narrow share of the population aged 30 to 34.
Lifelong learning	Lifelong learning encompasses all purposeful learning activity, whether formal, non-formal or informal, undertaken on an ongoing basis with the aim of improving knowledge, skills and competence.
Scientific co-publications	International scientific co-publications are a proxy for the quality of scientific research as collaboration increases scientific productivity
Most-cited publications	The indicator is a measure for the efficiency of the research system as highly cited publications are assumed to be of higher quality.
INVESTMENTS	
R&D expenditure public sector	R&D expenditure represents one of the major drivers of economic growth in a knowledge-based economy. Trends in the R&D expenditure indicator provide key indications of the future competitiveness and wealth of a region.
R&D expenditure business sector	The indicator captures the formal creation of new knowledge within firms. It is particularly important in the science-based sector (pharmaceuticals, chemicals and some areas of electronics), where most new knowledge is created in or near R&D laboratories
Non-R&D innovation expenditures	Several of the components of innovation expenditure, such as investment in equipment and machinery and the acquisition of patents and licenses, measure the diffusion of new production technology and ideas
INNOVATION ACTIVITIES	
Product or process innovators	Technological innovation as measured by the introduction of new products and processes is key to innovation in manufacturing activities.
Marketing or organisational innovators	Many firms, in particular in the service sectors, innovate through nontechnological forms of innovation. Examples of these are organisational innovations.
SMEs innovating in-house	This indicator measures the degree to which SMEs that have introduced any new or significantly improved products or production processes have innovated in-house. The indicator is limited to SMEs, because almost all large firms innovate
Innovative SMEs collaborating with others	Complex innovations often depend on companies' ability to draw on diverse sources of information and knowledge, or to collaborate on the development of an innovation. The indicator measures the flow of knowledge between public research institutions and firms, and between firms and other firms.
Public-private co-publications	This indicator captures public-private research linkages and active collaboration activities between business sector researchers and public sector researchers resulting in academic publications
PCT patent applications	The capacity of firms to develop new products determines their competitive advantage.
Trademark applications	Trademarks are an important innovation indicator, especially for the service sector. The Community trademark fulfils the three essential functions: it identifies the origin of goods and services, guarantees consistent quality through evidence of the company's commitment *vis-à-vis* the consumer, and is a form of communication, a basis for publicity and advertising
Design applications	A design is the outward appearance of a product or part of it resulting from the lines, contours, colours, shape, texture, materials and/or its ornamentation.
IMPACTS	
Hi-tech employment (Employment in MHT manufacturing & knowledge-intensive services)	The share of employment in medium-high/high-tech manufacturing and knowledge-intensive as percentage of the total workforce. It is an indicator of the manufacturing economy that is based on continual innovation through creative, inventive activity and also of knowledge-intensive services that can be provided directly to consumers, such as telecommunications and that provide inputs to the innovative activities of other firms in all sectors of the economy as this increases productivity throughout the economy and support the diffusion of a range of innovations, in particular those based on ICT
New sales (Sales of new-to-market and new-to-firm innovations)	This indicator measures the turnover of new or significantly improved products and includes both products which are only new to the firm and products which are also new to the market. The indicator thus captures both the creation of state-of-the-art technologies (new to market products) and the diffusion of these technologies (new to firm products)

Source: adapted from the European Commission (2019b) Regional Innovation Scoreboard 2019 Methodology Report

Table 2 – Model summaries

Model no.	R	R Square	Adjusted R Square	Std. Error of the Estimate
Hi-tech employment (Employment in MHT manufacturing & knowledge-intensive services)				
Model no. 1	0,612a	0,374	0,371	0,149
Model no. 2	0,631b	0,399	0,393	0,147
Model no. 3	0,653c	0,426	0,418	0,144
Model no. 4	0,666d	0,444	0,433	0,142
Model no. 5	0,676e	0,457	0,443	0,140
New sales (Sales of new-to-market and new-to-firm innovations)				
Model no. 1	0,551f	0,304	0,300	0,154
Model no. 2	0,631g	0,398	0,393	0,143
Model no. 3	0,663h	0,440	0,432	0,139
Model no. 4	0,674i	0,455	0,445	0,137
Model no. 5	0,682j	0,466	0,453	0,136
Model no. 6	0,692k	0,479	0,464	0,135

a. Predictors: (Constant), R&D expenditure business sector

b. Predictors: (Constant), R&D expenditure business sector, Innovative SMEs collaborating with others

c. Predictors: (Constant), R&D expenditure business sector, Innovative SMEs collaborating with others, Population with tertiary education

d. Predictors: (Constant), R&D expenditure business sector, Innovative SMEs collaborating with others, Population with tertiary education, Lifelong learning

e. Predictors: (Constant), R&D expenditure business sector, Innovative SMEs collaborating with others, Population with tertiary education, Lifelong learning, Public-private co-publications

f. Predictors: (Constant), Most-cited publications

g. Predictors: (Constant), Most-cited publications, Innovative SMEs collaborating with others

h. Predictors: (Constant), Most-cited publications, Innovative SMEs collaborating with others, Public-private co-publications

i. Predictors: (Constant), Most-cited publications, Innovative SMEs collaborating with others, Public-private co-publications, Non-R&D innovation expenditures

j. Predictors: (Constant), Most-cited publications, Innovative SMEs collaborating with others, Public-private co-publications, Non-R&D innovation expenditures, Lifelong learning

k. Predictors: (Constant), Most-cited publications, Innovative SMEs collaborating with others, Public-private co-publications, Non-R&D innovation expenditures, Lifelong learning, Trademark applications

Table 3 – Regression coefficients

Model no.		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
Hi-tech employment (Employment in MHT manufacturing & knowledge-intensive services)								
5	(Constant)	0,210	0,030		7,109	0,000		
	R&D expenditure business sector	0,496	0,073	0,551	6,779	0,000	0,406	2,460
	Innovative SMEs collaborating with others	-0,145	0,046	-0,196	-3,135	0,002	0,691	1,447
	Population with tertiary education	0,192	0,059	0,200	3,255	0,001	0,712	1,405
	Lifelong learning	-0,186	0,060	-0,218	-3,070	0,002	0,534	1,874
	Public-private co-publications	0,178	0,080	0,206	2,220	0,028	0,313	3,192
New sales (Sales of new-to-market and new-to-firm innovations)								
6	(Constant)	0,126	0,041		3,089	0,002		
	Most-cited publications	0,615	0,077	0,544	7,953	0,000	0,525	1,904
	Innovative SMEs collaborating with others	0,291	0,045	0,409	6,446	0,000	0,612	1,634
	Public-private co-publications	-0,197	0,060	-0,237	-3,258	0,001	0,463	2,158
	Non-R&D innovation expenditures	0,129	0,052	0,130	2,464	0,015	0,887	1,127
	Lifelong learning	-0,136	0,058	-0,163	-2,342	0,020	0,510	1,959
	Trademark applications	0,122	0,052	0,136	2,332	0,021	0,719	1,390

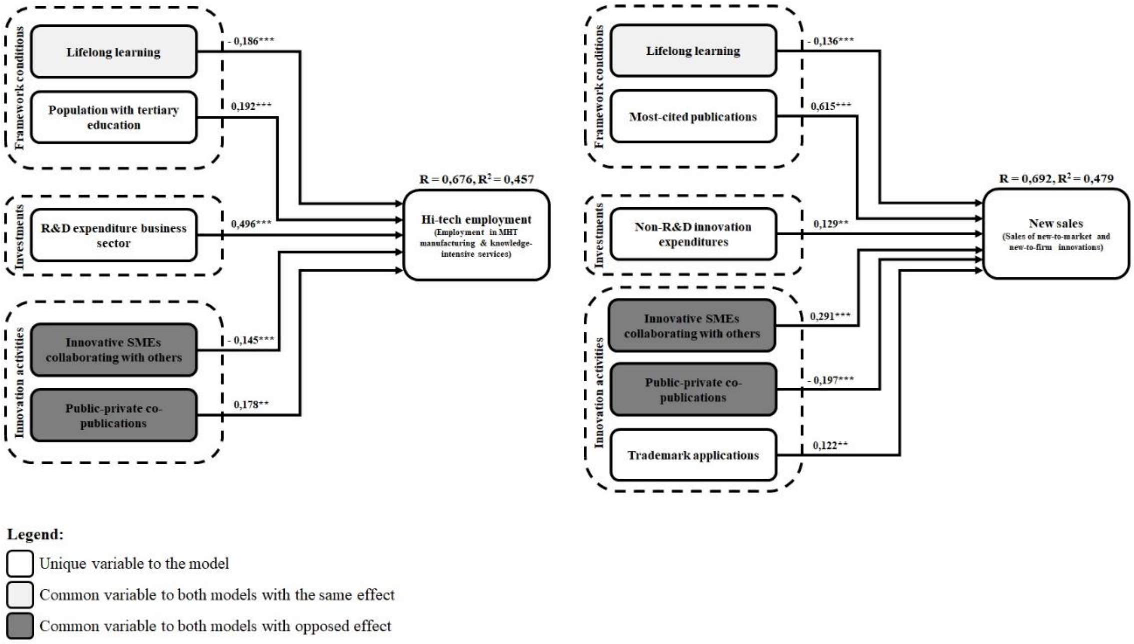

Figure 1 – Regional innovation impact models

Appendix 1 – Correlations between variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
1. Population with tertiary education	1															
2. Lifelong learning	,494**	1														
3. Scientific co-publications	,559**	,590**	1													
4. Most-cited publication	,286**	,546**	,638**	1												
5. R&D expenditure public sector	,400**	,450**	,807**	,511**	1											
6. R&D expenditure business sector	,397**	,557**	,588**	,520**	,498**	1										
7. Non-R&D innovation expenditure	-,156*	-,056	-,016	-,024	,139*	,045	1									
8. Product or process innovators	,181**	,445**	,481**	,507**	,530**	,428**	,441**	1								
9. Marketing or organisational innovators	,188**	,440**	,493**	,560**	,544**	,445**	,376**	,885**	1							
10. SMEs innovating in-house	,149*	,420**	,482**	,509**	,516**	,439**	,421**	,968**	,878**	1						
11. Innovative SMEs collaborating with others	,388**	,400**	,398**	,416**	,361**	,248**	,255**	,558**	,492**	,515**	1					
12. Public-private co-publications	,499**	,664**	,787**	,641**	,622**	,792**	-,025	,454**	,496**	,435**	,326**	1				
13. PCT patent applications	,274**	,621**	,552**	,602**	,476**	,826**	,025	,466**	,491**	,462**	,234**	,771**	1			
14. Trademark applications	,411**	,431**	,462**	,396**	,341**	,501**	-,196**	,242**	,269**	,276**	,017	,501**	,492**	1		
15. Design applications	,108	,170**	,162*	,219**	,112	,439**	-,044	,110	,070	,165*	-,104	,254**	,431**	,584**	1	
16. Employment MHT manufacturing & knowledge-intensive services	,340**	,235**	,404**	,291**	,243**	,639**	-,024	,205**	,222**	,236**	,042	,526**	,489**	,383**	,357**	1
17. Sales of new-to-market and new-to-firm innovations	,167*	,202**	,318**	,514**	,228**	,214**	,190**	,416**	,415**	,428**	,497**	,216**	,223**	,151*	,060	,106